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EFFECTS OF DELAYED REINFORCEMENT ON INFANT VOCALIZATION RATE

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Three previous studies have failed to demonstrate conditioning in infants using a 3-s delay of reinforcement. The effects of a delayed reinforcement schedule on vocalization rates therefore were explored in a single-subject repeated-reversal experimental design for 3 4- to 6-month-old normally developing infants. Each infant received delayed social reinforcement from his or her parent for vocalizing. The comparison condition was a schedule of differential reinforcement of behavior other than vocalizations to control for elicitation by social stimulation. An operant level of infant vocalizations was the initial condition, after which the differential reinforcement schedule was implemented in an across-subjects multiple baseline design. Infants' vocalization rates increased above levels measured during differential reinforcement following onset of the delayed reinforcement condition. Also, vocalization rates decreased during differential reinforcement compared to operant levels. The successful use of delayed reinforcement schedules with infants in this study, as opposed to others, is discussed in terms of procedural differences among them.

Key words: delayed reinforcement, vocalizations, differential reinforcement of other behavior, social reinforcement, methodology, infants

Dating back to Plato and Aristotle, the notion of temporal contiguity has been invoked as a relevant feature in stimulus association (Leahey, 1980). When the temporal interval between a response and a consequence is lengthened, the subsequent association may be weaker than associations formed with more contiguous events. The association between delayed reinforcement and responding has been investigated in several species, including rats (Grice, 1948; Wolfe, 1934), pigeons (Dews, 1960; Ferster, 1953; Gleeson & Lattal, 1987; Sizemore & Lattal, 1977; Williams, 1976), and monkeys (Ferster & Hammer, 1965), in addition to human infants (Millar, 1972; Millar & Watson, 1979; Ramey & Ourth, 1971) and children (R. Baer, Williams, Osnes, & Stokes, 1984; Fowler & Baer, 1981).

Studies of nonhumans indicate that delayed reinforcement does result in response learning, although the response rate or speed of acquisition is somewhat slower than that associated with immediate reinforcement. Williams (1976), for example, found that pigeons, given repeated exposure to 5-s delayed reinforcement for key pecking, displayed higher response rates than yoked-control pigeons receiving response-independent reinforcement. Similarly, Sizemore and Lattal (1977) found that when pigeons were presented with variable-interval (VI) schedules, VI-plus-delay schedules, and variable-time (VT) schedules for key pecking, the response rate declined with the change from VI to VI delay, and with the subsequent change from VI delay to VT. Sizemore and Lattal (1987) also found that reductions in key pecking from immediate reinforcement were smaller under delayed reinforcement schedules than under noncontingent reinforcement.

Although there is an apparent reduction in response rate produced by delayed reinforcement when compared to immediate reinforcement, nonhumans have responded under long delays when these delays were associated with secondary reinforcers. Ferster and Hammer (1965), for example, trained a monkey to key press for reinforcement delayed 24 hr, using a white light as a signal for the lack of availability of reinforcement during the delay in-

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terval. In addition, Wolfe (1934) demonstrated that rats in a discrimination box could perform a choice task without any significant response reduction with delays of reinforcement up to 30 s. Further, the rats learned the task with delays of 1 to 10 min, although those delays did retard learning to some extent. The task required the animals to choose between two alleys that were blocked by differently colored cards. Only one of the alleys led to the detention chamber, which was followed by access to food on a delay schedule. The card color associated with access to the detention chamber may have served as a secondary reinforcer for the correct card choice, bridging the gap between the choice response and the delivery of food. The successful use of such long delays of reinforcement in these two studies may be attributed to the presence of stimuli, such as color and light, that signaled the availability of reinforcement. Thus, research indicates that nonhumans learn a variety of tasks under a wide range of delay conditions.

Studies on human infants, in contrast, have failed to demonstrate learning under short delays of reinforcement with infants under 6 months of age (Millar, 1972; Millar & Watson, 1979; Ramey & Ourth, 1971). Specifically, Millar and Watson (1979) and Ramey and Ourth (1971) conducted experiments in which infants were assigned to different delay groups. After a 1-min baseline, infants were exposed to a 3- or 6-min contingency phase in which reinforcement was delayed. The delays were 0, 3, 6, or 10 s. The contingency phase was then followed by a 2-min (Ramey & Ourth, 1971) or 3-min (Millar & Watson, 1979) extinction phase. Both Millar and Watson (1979) and Ramey and Ourth (1971) were able to condition infants' motor or vocal responding, respectively, when the delay was 0 s. Nevertheless, no conditioning was demonstrated in either study when the delay was 3 s or longer.

On the other hand, Millar (1972) found that older infants between 6 and 7 months of age responded if the delay was 2 s or less. Millar presented groups of 6- to 7-month-old infants with a motor task in which pulling nylon cords attached to their sleeves produced audiovisual feedback. One-, 2-, and 3-s delayed consequences were compared to no stimulation, immediate stimulation, and noncontingent stimulation across subjects. The 1- and 2-s delays to reinforcement resulted in responding above the level obtained during noncontingent stimulation but below that of immediate stimulation. The 3-s delayed consequence did not produce responding different from that of the noncontingent stimulation. When the time period during which the infant was exposed to the delay contingency was extended from 3 min to 6 min, increased responding was still observed for only the 1- and 2-s delay groups. Millar (1972) concluded that infants' short-term memory deficits prevent them from processing information presented with delays greater than 2 s.

The failure to condition infant responding in the above studies under delays of reinforcement longer than 3 s could have occurred for any of the following reasons: First, the delay was unsignaled. Second, nontarget responses, which were competing or incompatible with the target response, may have been adventitiously reinforced during the delay, and thus may have interfered with reinforcement of the target response. If the infant's exposure to the delayed reinforcer was extended across sessions or days, these nontarget responses may decrease because the probability of the reinforcer following these responses would be lower than the probability of the reinforcer following the target response. Third, the pattern and amount of reinforcement during the 3-s (or longer) delay were different from those of immediate reinforcement or reinforcement under shorter delays. Specifically, during a given session, the amount of time in the delay would be subtracted from the total time available for responding and for delivering consequences. As a result, in fairly short experimental sessions, there are fewer opportunities for delayed reinforcement, and thus fewer opportunities to be exposed to the contingencies.

The purpose of the present study was to demonstrate the effectiveness of delayed reinforcement on the vocalization rate of young infants. The use of a single-subject repeated-reversal experimental design allowed each infant to have extended exposure to the delay contingency. The comparison condition was a schedule of differential reinforcement of behavior other than vocalizations (DRO).

The DRO condition was selected as a second baseline measure to deliver rates of social reinforcement comparable to those in the delayed reinforcement condition. If social reinforcement occurred more often in delayed reinforcement than in DRO, then any subsequent increase in vocalization rate during delayed reinforcement could be attributed to elicitation by parental stimulation, rather than the result of the contingencies of social stimulation. DRO has been used successfully in the past by Poulson (1983) as a control procedure against which to compare continuous reinforcement (CRF) of vocalizations emitted by 3-month-old infants. Poulson (1984) argued that the use of a DRO schedule ruled out the possibility of adventitious reinforcement delivered during a putative response-independent schedule of reinforcement for infant vocalizations. As an expansion of Poulson's (1983) procedure, an operant level of vocalization was included in the present study prior to DRO to provide information about the possible effects of DRO itself on infant behavior. DRO was introduced following operant level in a multiple baseline design.

METHOD

Subjects

Three normally developing infants served as subjects. Their parents were contacted through local newspapers in the borough of Queens. Beth, David, and Jay were 104, 140, and 150 days old, respectively, at the beginning of the study. At the time of the final experimental sessions, the infants were 168, 192, and 197 days old. Ten to 30 daily sessions were conducted three to four times per week over a 28- to 88-day period.

The Bayley Scales of Infant Development, Mental Development Index (Bayley, 1969) were given to each infant within 8 days of the experiment. All infants scored within the normal range (M = 100); Jay and David each scored 131 and Beth scored 105. Each infant was accompanied by the same parent during all experimental sessions (only the mothers participated). Two mothers were white and one was black, and all of them had completed at least 1 year of college. One mother was a nursery school teacher, another taught elementary school, and the third was a housewife.

Setting and Apparatus

The study took place in an infant laboratory located in a large university building. The laboratory was fully carpeted and was furnished with a couch and some toys to provide a home-like atmosphere. A three-panel screen (61 cm by 152 cm) with a window opening (30 cm by 43 cm) in the center panel was located on the floor. An infant car seat was placed inside the screen, and an ottoman for the parent to sit on was placed outside the screen in front of the window. The window opening, through which the parent could play with and touch the infant, was at eye level for both parent and infant. The opening was covered with a beige Venetian blind (76 cm by 43 cm) with 2.5-cm slats. The blind remained closed, except during the operant-level baseline when it was open. When the blind was down, both parent and infant were unable to see each other.

Three 28-V incandescent bulbs with colored crystals served as signal lights. A yellow signal light was positioned on the upper left side of the window facing the parent, 11 cm from the window opening. A corresponding red signal light was positioned on the upper right corner of the window facing the infant, 11 cm from the window opening. The signal lights were activated by foot switches pressed by observers according to the schedule that was in effect. A green light was located below the signal light on the parent's side of the screen.

Two observers sat behind the infant and scored infant vocalizations on portable event recorders (S & K Computer Products). Venetian blind operation and activation of the signal lights were automatically recorded with solenoid switches that depressed keys on the event recorder.

General Procedure

Infants and parents attended three or four 12-min sessions per week over a period of 1 to 3 months. The parent brought the infant to the laboratory, seated the infant in the car seat behind the screen, and then sat outside the screen facing the infant through the open window. An experimental session began when the infant and parent were seated facing one another (during operant level) or when the parent lowered the blind.

The independent variable was the schedule of social reinforcement. Two schedules were presented: 3-s delayed reinforcement and a schedule of differential reinforcement of behavior other than vocalizations (DRO). Social reinforcement was defined as the raising of the window blind. Social reinforcement occurred as follows: Each of the observers turned on the signal lights on both sides of the screen using a foot switch, indicating the onset of the delay period. The lights would illuminate only if both foot switches were pressed simultaneously. A green light, located only on the parent's side of the screen, was timed from the onset of the signal light, and its onset indicated the end of the delay period. In the DRO condition, the two lights on the parent's side of the screen were illuminated simultaneously. Onset of the green light served to signal the parent to raise the blind. An 80-dB buzzer automatically signaled the parent to lower the blind 5 s after its opening. While the blind was raised, the parent was asked to make eye contact with the infant while saying "Good baby!" and then to play with the infant through the window opening. The timing of blind raising and lowering was measured automatically by a microswitch on the window blind.

The rate of infant vocalizations served as the dependent variable. A vocalization was defined as a voiced sound of any duration emitted by the infant. A 1-s or longer pause defined the beginning of a new vocalization. The onset of infant vocalizations was recorded by two independent observers on event recorders during the experimental sessions.

Sessions were terminated if the infant fussed or cried for over 1 min. Crying that occurred for less than 1 min was treated procedurally as a vocalization. That is, consequences were delivered according to the schedule in effect. In the data analysis, however, crying was omitted from the calculation of vocalization rate.

Experimental Design and Conditions

The present study was conducted as a single-subject repeated-reversal experimental design embedded within a multiple baseline across subjects design (D. Baer, Wolf, & Risley, 1968). Three experimental conditions were used in the following order: (a) operant level, (b) a schedule of differential reinforcement of behavior other than vocalizations (DRO), and (c) a 3-s delayed reinforcement schedule for vocalizations. The second and third conditions were alternated twice in a BCBC repeated-reversal design. Condition changes occurred when the graphed data were judged to be stable in the current phase.

In the operant level baseline, the window blind remained open for each session. The parent was asked to play with the infant as she would at home by talking to and touching the infant through the window opening and by showing toys to the infant. The DRO condition was introduced following this baseline in a multiple baseline design to assess the effects of DRO on the rate of infant vocalizations.

In the DRO condition, as long as the infant did not vocalize the blind was opened every 2 s for a short period of social stimulation by the parent, as described under the General Procedure. If the infant vocalized during DRO while the blind was down, the window opening was delayed until no vocalizations occurred for 4 s. These DRO parameters were used successfully by Poulson (1983). The use of temporally different parameters for the reinforcer–reinforcer and response–reinforcer intervals may facilitate control over infant behavior.

The delayed reinforcement condition was automated as described above, such that there was a 3-s delay between the onset of the infant's initial vocalization after the window blind was closed and the onset of the green light to signal the parent to raise the window blind. Infant vocalizations made within the delay interval or during the window-open period were recorded but did not have any programmed consequences. Only vocalizations that occurred when the window was open were excluded from the analysis of vocalization rate. Vocalizations occurring during the window-open periods were analyzed separately.

Data Analysis

Data were analyzed in 3-min intervals. Intervals that were terminated prior to 120 s to meet the infant's needs were discarded. Accordingly, a full 180 s was obtained in 90% of 242 intervals throughout the study. Specifically, 100% of 40 intervals were used for David, 90% of 90 intervals were used for Jay, and 88% of 112 intervals were used for Beth. Equipment failure resulted in discarding six intervals for all infants. One interval was discarded for Beth in operant level. For Jay, two intervals were discarded from DRO and three were discarded from the delayed reinforcement condition. No intervals were discarded for David.

Because the duration of the window-open reinforcement episodes was free to vary across parents and sessions, the measure of the infant's vocalization rate was adjusted in the following manner: The number of vocalizations (when the window was open) and the number of seconds that the window was open were subtracted from the data prior to the calculation of the rate of vocalizations during each 3-min interval. Nevertheless, vocalizations that occurred during the window-open periods were recorded and analyzed separately.

Fussing or crying was measured using a 5-s interval-sampling procedure and was reported in terms of percentage of 5-s intervals in which any fussing or crying occurred.

Interobserver Agreement

Interobserver agreement for the onset of vocalizations was calculated on a point-by-point basis by dividing the number of agreements by the sum of the number of agreements and disagreements and multiplying by 100. Vocalizations recorded by both observers during a 1-s interval were counted as agreements. Overall interobserver agreement was 83% for 190 3-min intervals. Interobserver agreement for vocalizations was 83% for 54 3-min operant level intervals (range, 80% to 90%), 85% for 60 DRO intervals (range, 83% to 85%), and 81% (range, 81% to 82%) for 76 delayed reinforcement intervals.

Interobserver agreement for the occurrence of fussing or crying was calculated by dividing the number of 5-s intervals in which both observers reported fussing or crying by the number of 5-s intervals in which both observers agreed and disagreed about the occurrence of fussing or crying. Interobserver agreement was 92% for 90 5-s intervals containing fussing or crying during operant level, 90% for 78 5-s intervals during DRO, and 85% for 15 5-s intervals during delayed reinforcement.

Interobserver agreement was obtained during 86% of the 219 3-min intervals used in the data analysis because of occasional software and hardware equipment failure. Interobserver agreement was obtained for 79% of the 68 intervals during operant level for each of the 3 infants. During DRO, interobserver agreement was calculated for 86% of the 70 intervals. During delayed reinforcement, interobserver agreement was calculated for 91% of the 84 intervals.

RESULTS

Figure 1 presents the rate of infant vocalizations for each 3-min interval. There are two primary sets of results. One focuses on the effect of delayed reinforcement and the other on the effects of DRO itself on infant vocalization rates. First, we will examine the comparison of the delayed reinforcement and DRO conditions, as shown with the reversal design.

All infants systematically demonstrated an increased rate of vocalization during the 3-s delayed reinforcement condition compared to the DRO condition in the repeated-reversal design. The horizontal lines in Figure 1 illustrate the density of social reinforcement (rate of window openings) per experimental condition for each infant. In general, the rate of window opening was similar across infants and across experimental conditions. A mean of 4.91 window openings occurred over 70 3-min components during DRO. During delayed reinforcement, there was an overall mean of 4.09 window openings for 84 components. For five of six comparisons between DRO and delayed reinforcement for all 3 infants, the rates of window openings were systematically higher during DRO.

The comparison between operant level and DRO can also be seen in Figure 1. All infants' average vocalization rates decreased systematically with the introduction of the DRO condition. For Jay, however, that decrease was smaller, consisting primarily of a decrease in the top range of scores during DRO. During the window-open periods, the putative reinforcing events, infants did not systematically change vocalization rates with the introduction of changes in condition.

The percentage of 5-s intervals that contained fussing or crying was as follows: During the operant level baseline, fussing or crying occurred in 4% of 4,080 5-s intervals. During the first DRO condition, fussing or crying occurred in 3% of 2,880 5-s intervals. During the first delay condition, they occurred in 1% of 3,300 5-s intervals. During the second DRO condition, fussing or crying occurred in 4% of 1,440 5-s intervals. During the second delay condition, fussing or crying occurred in 1% of 1,740 5-s intervals.

DISCUSSION

In the present study, delayed social reinforcement was effectively used by parents with their 4- to 6-month-old infants. When infants' vocalizing was reinforced on a 3-s delayed reinforcement schedule, their rates of vocalization systematically increased. The DRO schedule systematically decreased the rates of

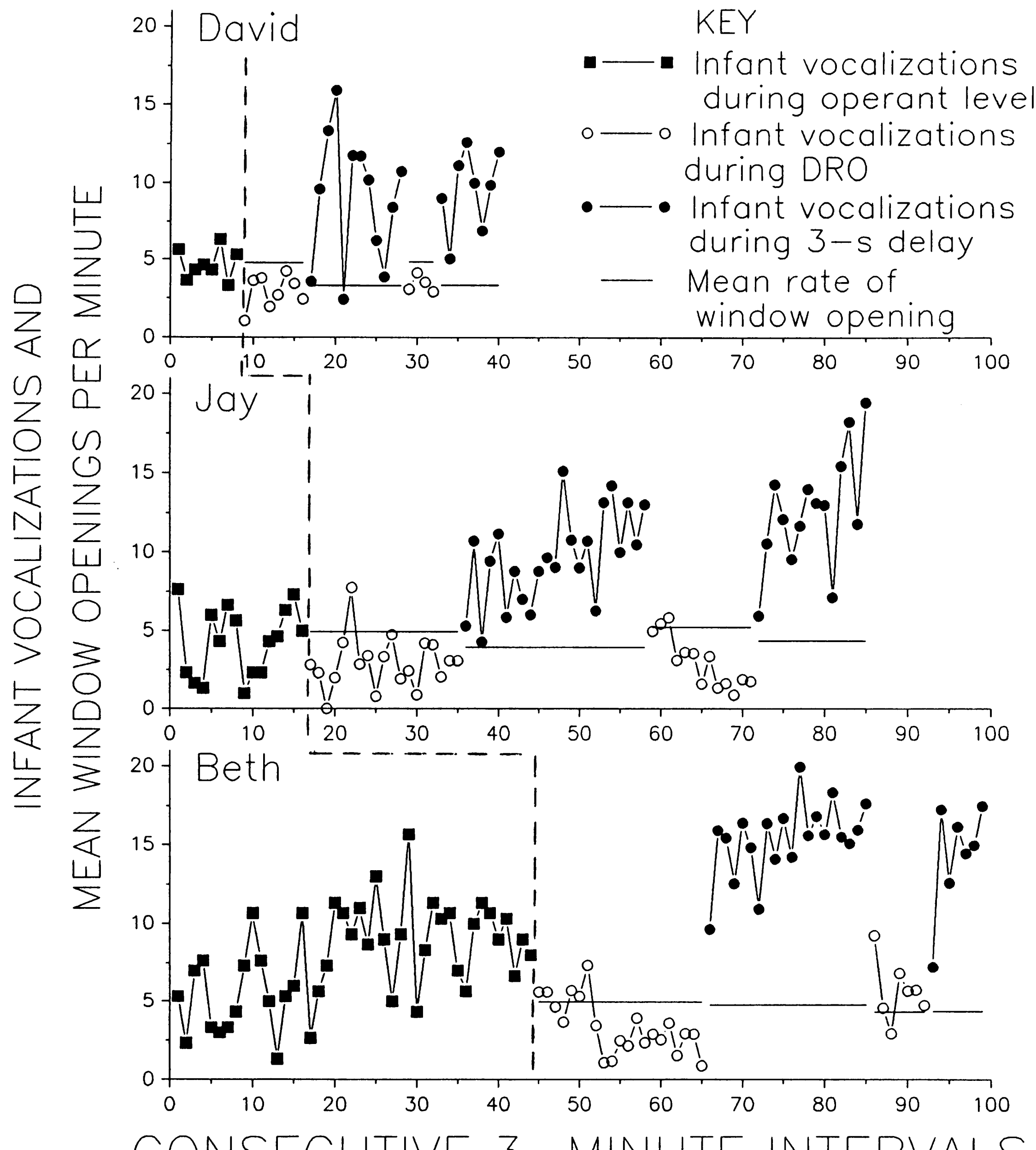

Fig. 1. Vocalizations per minute emitted by David, Jay, and Beth during the operant level baseline (closed squares), differential reinforcement of other than vocalization (DRO) (open circles), and the 3-s delayed reinforcement condition (closed circles) for consecutive 3-min intervals. The DRO condition was systematically introduced following operant level in a multiple baseline design across subjects. Both the DRO and delay conditions were repeated in a single-subject reversal design. Mean rates of window opening during the DRO and delay conditions are shown with horizontal lines.

vocalization below the rates obtained during delayed reinforcement. Because vocalization rates were higher during delayed reinforcement than during DRO, and because the total amount of stimulation during DRO was equal to or higher than rates under delayed reinforcement, one may conclude that delayed reinforcement caused the increase in vocalization rates. Furthermore, it is unlikely that higher rates of stimulation under DRO than under delayed reinforcement in some sense suppressed the vocalization rate during DRO, because in one instance (Beth's second DRO phase), the rate of stimulation under DRO was below the rates of stimulation in the previous delayed reinforcement and DRO conditions. Nevertheless, the rate of responding during the second DRO was lower than during either delayed reinforcement condition. Thus, we have demonstrated contingency control of infant responding with delayed reinforcement.

The present results contrast with both the findings and inferences made by Millar (1972), Millar and Watson (1979), and Ramey and Ourth (1971) regarding delayed reinforcement in infants. A major procedural difference between the above studies and the present study was the availability of more extensive repeated exposure to the contingency in the latter. This extensive repeated exposure may have offset any superstitious conditioning that might have occurred when the delayed contingencies immediately followed a nontarget response, because the probability of nontarget responses being followed immediately by the consequence again was in fact lower than the probability of the target response producing the consequence. Consistent with this interpretation, the literature on nonhumans indicates that increased exposure was required to promote acquisition when increased delays of reinforcement were used (Grice, 1948). In Grice's research, groups of rats learned a maze-discrimination task in which reinforcement was delivered after a range of delays. In the 0-s delay group, the task was performed to criterion within a median of 20 trials, whereas the 2-s delay group needed a median of 290 trials. The 5-s delay group needed a median of 580 trials, and the 10-s delay group did not meet criterion within 1,440 trials. Ramey and Ourth (1971), Millar (1972), and Millar and Watson (1979) may have failed to obtain conditioning of infant behavior with delayed reinforcement because their procedures provided exposure to the contingency in only one 3- or 6-min conditioning phase during a single session. In contrast, the current procedure presented the contingency over 10 to 30 daily 12-min sessions over 28 to 88 days. Thus, our infants were provided with significantly more exposure to the contingency than were the infants in previous studies investigating delayed reinforcement.

The data obtained in the present study with human infants are consistent with data from previous studies involving older children and nonhumans. It may be that our procedures were more similar to those used in the nonhuman and child literature. Specifically, many of the studies with nonhumans and studies with older children involved the repeated presentation of the delayed reinforcement contingency within subjects and across sessions (R. Baer et al., 1984; Ferster & Hammer, 1965; Fowler & Baer, 1981; Gleeson & Lattal, 1987; Sizemore & Lattal, 1977). Although Millar (1972), Millar and Watson (1979), and Ramey and Ourth (1981) used within-subject designs, they did not provide repeated exposure across daily sessions, nor was a criterion of stability achieved prior to changing experimental conditions.

Signaling of the delay period also differentiates the present study from previous studies of delayed reinforcement in infants. In the present study, a red light signaled the delay period to reinforcement. Such stimuli were also incorporated into the designs of several of the experiments with nonhumans (Ferster & Hammer, 1965; Wolfe, 1934). These stimuli may have become secondary reinforcers and thus may have bridged the delay between the response and the reinforcer. Further investigation is needed to determine the importance of signaled, as opposed to unsignaled, delay.

Although Millar's (1972) study (with 1- to 2-s delayed reinforcement) and the present study (with 3-s delayed reinforcement) demonstrated successful infant conditioning with delayed reinforcement, the parameters of delayed reinforcement effective with infants remain unknown. Research with nonhumans may provide examples of specific strategies that could be used to extend the delay period without altering the effectiveness of the reinforcer for human infants. Ferster (1953), for example, obtained conditioning in pigeons with greater delays of reinforcement by slowly fading in longer delays over time. Further investigation is needed to determine the range of conditions under which delayed reinforcement is effective with human infants.

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